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Sandia National Laboratories
Waste Isolation Pilot Plant

Analysis Plan for the analysis of Direct Releases Part of the Technical Baseline Migration

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1 INTRODUCTION AND OBJECTIVES

This analysis plan directs analyses of direct releases for the Technical Baseline Migration (TBM) study. Direct releases, in the context of the Waste Isolation Pilot Plant, consist of the release of radionuclides to the surface as a result of inadvertent drilling intrusion to the repository. The four direct release mechanisms that have been studied in WIPP performance assessment (PA) are cuttings, cavings, spallings and direct brine release (DBR). Prior performance assessment and impact assessment studies used the 1996 Compliance Certification Application (CCA) (U.S. DOE, 1996) and the 1997 Performance Assessment Verification Test (PAVT) (PAVT, 1997) as a baseline, resulting in two baselines. This proves problematic because new calculations must be compared to both, resulting in duplication of effort. The TBM attempts to produce a single baseline to be used for future analyses. The TBM will incorporate an important change from the CCA and PAVT baselines, namely the Option D panel closure specified by EPA permit (EPA, 1998), which was not explicitly modeled in the CCA and PAVT analyses.

This study involves the direct releases component of the overall TBM analysis. The aim of this study is to produce direct releases analyses for the TBM. The study will incorporate additions/changes included in the vertical BRAGFLO 10,000-year calculations that affect direct releases (Stein, 2002; Lord and Hadgu 2002; and Hansen and Leigh, 2002). It will also include changes that only affect direct releases. Changes to the 10,000-year BRAGFLO calculations will result in changes to the pressure and saturation histories in the repository, and such changes in turn impact spallings and DBR. The analyses defined in this plan will provide the effect and magnitude of these changes by comparisons of results to those obtained from the PAVT calculations.

2 APPROACH

The 10,000-year BRAGFLO calculations have introduced changes such as:

- Use of a new vertical TBM grid (shown in Figure 1) (Stein, 2002).
- Removal of the shaft system (Stein, 2002).
- Implementation of Option D panel closure system (EPA, 1998).
- Changes in the properties of the disturbed rock zone (DRZ).

These changes will directly impact direct brine release and spallings. Additional changes will also be made in direct release calculations. Thus, the direct releases analysis is planned to address these issues and others on radionuclide releases. The specific changes are discussed below.

2.1 Direct brine release

The following changes will be introduced into the CUTTINGS_S and DBR calculations for the TBM.

- Replace CCA/PAVT vertical grid with TBM vertical grid.
- Correct productivity index (PI) and flowing bottomhole pressure (FBHP) equations.
- Introduce Option D panel closure in DBR grid.
- Add CUTTINGS_S and DBR data to new database.
- Replace old SDB flat file (CUSP_TBM.SDB) with a new one that corresponds to the new database.
- Change the Material DRZ in the CCA/PAVT DBR grid with more appropriate materials for TBM.
- Divide DBR grid into three regions to reflect use of Option D panel closure.

2.1.1 Replace CCA/PAVT grid with TBM Vertical grid

The Direct Brine Release (DBR) model uses a horizontal BRAGFLO grid (Figure 1 shows CCA/PAVT grid). The initial conditions for the DBR simulations are obtained from the 10,000-year BRAGFLO calculations by transferring data from the vertical grid to the horizontal grid at time of intrusion. In the CCA and PAVT calculations the vertical grid was divided into four regions. Regions 1, 2 and 3 represented the three columns of the Rest of the Repository. Region 4 represented the single panel. The horizontal DBR grid was also subdivided into four corresponding regions. Volume averaged output variables were then transferred from a region in the vertical grid to a corresponding region in the horizontal DBR grid.

The new TBM grid (Figure 2) subdivides the rest of the repository into two (north and south ends). Also, the element numbers of the grid blocks in the single panel and the rest of the repository have changed. These changes have to be incorporated in the DBR calculations for TBM. For the calculations the following changes have to be made (see Figure 3):

- The three regions in the vertical grid for DBR use are:
    - Region 1 = The two columns of the north end of the rest of the repository (i.e. Elements 1444, 1442, 1440, 1443, 1441, 1439)
    - Region 2 = The two columns of the south end of the rest of the repository (i.e. Elements 1438, 1436, 1434, 1437, 1435, 1433)
    - Region 3 = Single (intruded) panel
- The three regions in the horizontal DBR grid are:
    - Region1 = Panels 1, 2, 7, 8 and 10.
    - Region 2 = Panels 3, 4, 6 and 9.
    - Region 3 = Panel 5

2.1.2 Correct PI and FBHP

A factor 2π was missing from the productivity index (PI) equation used in DBR calculations in the CCA and PAVT. Correcting the PI equation resulted in changes to the Flowing Bottomhole Pressure (FBHP) curve fits. As a result new FBHP curve fits have been introduced. This has been detailed in Hadgu et al. (1999). Both of these changes will be included in the DBR calculations for TBM.

2.1.3 Introduce Option D panel closure in DBR

The new TBM vertical grid explicitly models the Option D panel closure system. At the repository level (of interest to DBR), the Option D panel closure system consists of a concrete monolith and a drift (Stein, 2000), represented by two columns of grid blocks with distinct materials. The material PAN_SEAL (used in CCA/PAVT) was replaced by the TBM materials CONC_PCS (which is in the material database), CPCS_F (a derived material) and DRF_PCS (a derived material). To apply these changes to the DBR calculations, either the DBR grid must be modified to introduce CONC_PCS, CPCS_F and DRF_PCS, or effective permeabilities of these features must be introduced as material properties. To minimize changes to the DBR grid the panel closure will be represented with effective permeabilities. Since the drift (DRF_PCS) contains most of the pore volume of the panel closure, the rest of the material properties for the equivalent system will be the same as DRF_PCS. In the 10,000-year calculations DRF_PCS was given properties of the waste area, including creep closure (for panel closures in the waste-area). Thus, all properties for the panel closure, with the exception of permeability and porosity, will be the same as that of WAS_AREA. For permeability and porosity, effective values representing the concrete and the drift parts will be used. The effective permeabilities will be:

For x-axis: This is for materials in series. The effective permeability is a harmonic average of the two permeabilities:

$$k_{eff-X} = \frac{k_1 k_2 (d_1 + d_2)}{d_1 k_2 + d_2 k_1} \qquad (1)$$

where k_1 = permeability of CONC_PCS (sampled)
k_2 = permeability of DRF_PCS = 2.4×10^{-13} m^2
d_1 = thickness of CONC_PCS = 7.9 m
d_2 = thickness of DRF_PCS = 32.1 m

For y-axis: This is for materials in parallel. The effective permeability is a length weighted average of the two permeabilities:

$$k_{eff-Y} = \frac{k_1 d_1 + k_2 d_2}{d_1 + d_2} \quad (2)$$

The panel closures between Panels 9 and 10 (inner equivalent panels) have a different orientation than the rest of the panel closures. Thus, a new material PAN_SL2 (a derived parameter) has been assigned to represent them. The effective permeabilities for this case will be the reverse of the permeabilities for the rest of the panel closures. i.e.

$$k_{eff-X} = \frac{k_1 d_1 + k_2 d_2}{d_1 + d_2} \quad (3)$$

For y-axis: This is for materials in parallel. The effective permeability is a length-weighted average of the two permeabilities:

$$k_{eff-Y} = \frac{k_1 k_2 (d_1 + d_2)}{d_1 k_2 + d_2 k_1} \quad (4)$$

And the effective porosity will be:

$$\phi_{eff-Y} = \frac{\phi_1 d_1 + \phi_2 d_2}{d_1 + d_2} \quad (5)$$

where ϕ_1 = porosity of CONC_PCS
ϕ_2 = porosity of DRF_PCS

The above effective permeabilities and porosity will be implemented in the DBR grid and material representations.

2.1.4 Add CUTTINGS_S and DBR data to new parameter database

Some properties used in the CUSP calculations were not entered into the new database. They now will be entered. The variables are:

Material	Property
BLOWOUT	APORO (waste permeability – constant)
BLOWOUT	FGE (gravity effectiveness factor – distribution)
WAS_AREA	VOLSPALL (volume of spall – distribution)
WAS_AREA	PTHRESH (threshold pressure – constant)

VOLSPALL will be added to LHS1 for sampling. Although FGE is a distribution, it has not been added to LHS1. This parameter is derived from the CCA model for spallings. The CCA model was found inadequate by the conceptual model Pear Review Panel (Wilson et al.), and its parameters are no longer considered valid by Sandia National labs.

2.1.5 Replace old SDB flat file with a new one

CUSP uses a flat file CUSP_C97.SDB that has all material properties. This file will be updated to correspond to the new database.

2.1.6 Change CCA/PAVT representation of DRZ in the DBR grid

DBR analyses in the CCA treated all pillars and material surrounding panels as DRZ with a constant permeability of 1 x 10^{-15} m^2. In the PAVT the following changes were introduced for DBR runs:

The DRZ was divided into two materials:

- Pillars between rooms were assigned initial sampled DRZ permeability.
- Material between rooms and pillars was assigned DRZ permeability at time of intrusion. This permeability is the same as the initial sampled permeability unless fracturing occurs. In the event of fracturing in the DRZ before or at the intrusion time, this material was assigned the fractured permeability.

In the PAVT 10,000-year calculations the DRZ was sampled, with:

- Distribution: uniform
- Range: log permeability: -19.4 to –12.5 (3.98 x 10^{-20} to 3.16 x 10^{-13} m^2)
- Mean/Median = log permeability: -15.95 (1.12 x 10^{-16} m^2)

A study of the DBR results for the PAVT (PAVT, 1997) shows that when DRZ permeabilities are high, the entire repository becomes hydraulically connected. This is more evident when fractured permeabilities are assigned to the material surrounding rooms and panels, which includes the massive pillars (61 m thick) between panel closures. Such cases could produce unrealistic brine releases when combined with high pressures and high brine saturations. For the TBM, representation of DRZ in the DBR grid needs to be changed. The following describes the planned changes to be made together with reasons for the changes:

1. The pillars between rooms (within a panel) have dimensions of 30.5 m x 98.1 m. Physically the outer edges (a few meters deep) would be DRZ and the inner core would be Salado Halite. For brine release calculations these pillars could be represented by an effective permeability consisting of Salado Halite and DRZ. But because the size of the inner core is large compared to the DRZ outer edges,

the effective permeability would be very nearly the same as the Salado Halite. Thus, they will be represented as Salado halite.

2. The massive pillar (61 m x 98.1 m) between panel closures would also have DRZ in the outer edges. But use of Option D panel closure will heal any DRZ in contact with the panel closures. As discussed in (1) above, the effective permeability for this case would be very close to that of the Salado Halite. Thus, it will be represented as Salado halite.
3. The material between the full panels is represented as 5.12 m of DRZ, 45.96 m of Salado Halite and 5.12 m of DRZ. It is obvious that whatever the permeability of the DRZ, the 45.96 m thick Salado Halite will prevent any flow between the full panels. However, flow could occur in the 5.12 m thick DRZ surrounding the full panels. Thus, the 5.12 m thick DRZ will be assigned DRZ permeability at time of intrusion.
4. The 3.60 m thick boundary DRZ next to panel closures will be affected by Option D panel closure. It can be assumed that the extension of the concrete to the DRZ will cover the 3.60 m thickness. Thus, the 40 m length grid blocks will consist of 7.9 m of concrete and 32.1 m of DRZ. Since the DRZ part has a much larger pore volume than the concrete part, material properties of the equivalent material, with the exception of permeability and porosity, will be those of DRZ. As was done for the panel closures (Section 2.3.3), effective permeabilities and porosity will be used to represent the permeabilities and porosity of the two materials. The effective permeabilities are:

For x-axis: The effective permeability is a harmonic average of the two permeabilities:

$$k_{eff-X} = \frac{k_1 k_2 (d_1 + d_2)}{d_1 k_2 + d_2 k_1} \qquad 6)$$

where k_1 = permeability of CONC_PCS (sampled)
k_2 = permeability of DRZ = (sampled and subject to fracturing)
d_1 = thickness of CONC_PCS = 7.9 m
d_2 = thickness of DRZ = 32.1 m

For y-axis: This is for materials in parallel. The effective permeability is a length weighted average of the two permeabilities:

$$k_{eff-Y} = \frac{k_1 d_1 + k_2 d_2}{d_1 + d_2} \qquad (7)$$

And the effective porosity will be:

$$\phi_{eff-Y} = \frac{\phi_1 d_1 + \phi_2 d_2}{d_1 + d_2} \qquad (8)$$

where ϕ_1 = porosity of CONC_PCS
ϕ_2 = porosity of DRF_PCS

These permeabilities will be used to represent permeabilities in the grid blocks.

2.2 Cuttings and cavings

Cuttings and cavings will be calculated as in the 1997 PAVT.

2.3 Spallings

For the TBM analysis spallings will be calculated using the PAVT model. In the model a spall volume of 0 to 4.0 m^3 is randomly selected from a uniform distribution. The methods used in the PAVT analysis will be followed.

3 SOFTWARE LIST

All applicable software and version numbers are shown in Table 1.

Code Name	*Version*
ALGEBRA	2.35
BRAGFLO_DBR	4.10.02
CUTTINGS_S	5.04A
GENMESH	6.08
ICSET	2.22
LHS	2.41
MATSET	9.10
POSTBRAG	4.00
POSTLHS	4.07
PREBRAG	6.00
PRELHS	2.24
RELATE	1.43

Table 1. Software list for direct releases analyses

4 TASKS

Teklu Hadgu will perform analysis, documentation, and QA assisted by Byoung-Youn Park and David Lord. Rodger Coman will execute running of codes in a controlled environment, and storage of data in CMS. Steve Tisinger will provide database support.

Calculation runs, analysis and documentation are planned to be completed by July 31, 2002.

5 SPECIAL CONSIDERATIONS

There are no special considerations.

6 APPLICABLE PROCEDURES

Analyses will be conducted in accordance with the quality assurance (QA) procedures listed below:

Training: Training will be performed in accordance with the requirements in NP 2–1, Qualification and Training.

Parameter Development and Database Management: Selection and documentation of parameter values will follow NP 9–2. The database is to be managed in accordance with relevant technical procedure.

Computer Codes: New or revised computer codes that will be used in the analyses will be qualified in accordance with NP 19–1. All other codes unchanged since the PAVT are qualified under multi-use provisions of NP 19–1. Codes will be run on the Compaq Alpha platform using OpenVMS AXP, version 7.2.

Analysis and Documentation: Documentation will meet the applicable requirements in NP 9–1.

Reviews: Reviews will be conducted and documented in accordance with NP 6–1 and NP 9–1, as appropriate.

7 REFERENCES

EPA (U.S. Environmental Protection Agency), 1998. "40 CFR Part 194: Criteria for the Certification and Re-certification of the Waste Isolation Pilot Plant's Compliance with the 40 CFR Part 191 Disposal Regulations: Certification Decision; Final Rule. Federal Register", Vol. 63, No. 95, pp. 27353-27406, May 18, 1998. Office of Radiation and Indoor Air, Washington, D.C.

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U.S. DOE, 1996, Title 40 CFR Part 191 Compliance Certification Application for the Waste Isolation Pilot Plant. DOE/CAO-1996-2184.

Wilson, C., Porter, D., Gibbons, J, Oswald, E., Sjoblom, G., and Caporuscio, F., 1997 Conceptual Models Third Supplementary Peer Review Report, EPA Air Docket A-93-02, Item II-G-22, April 1997.

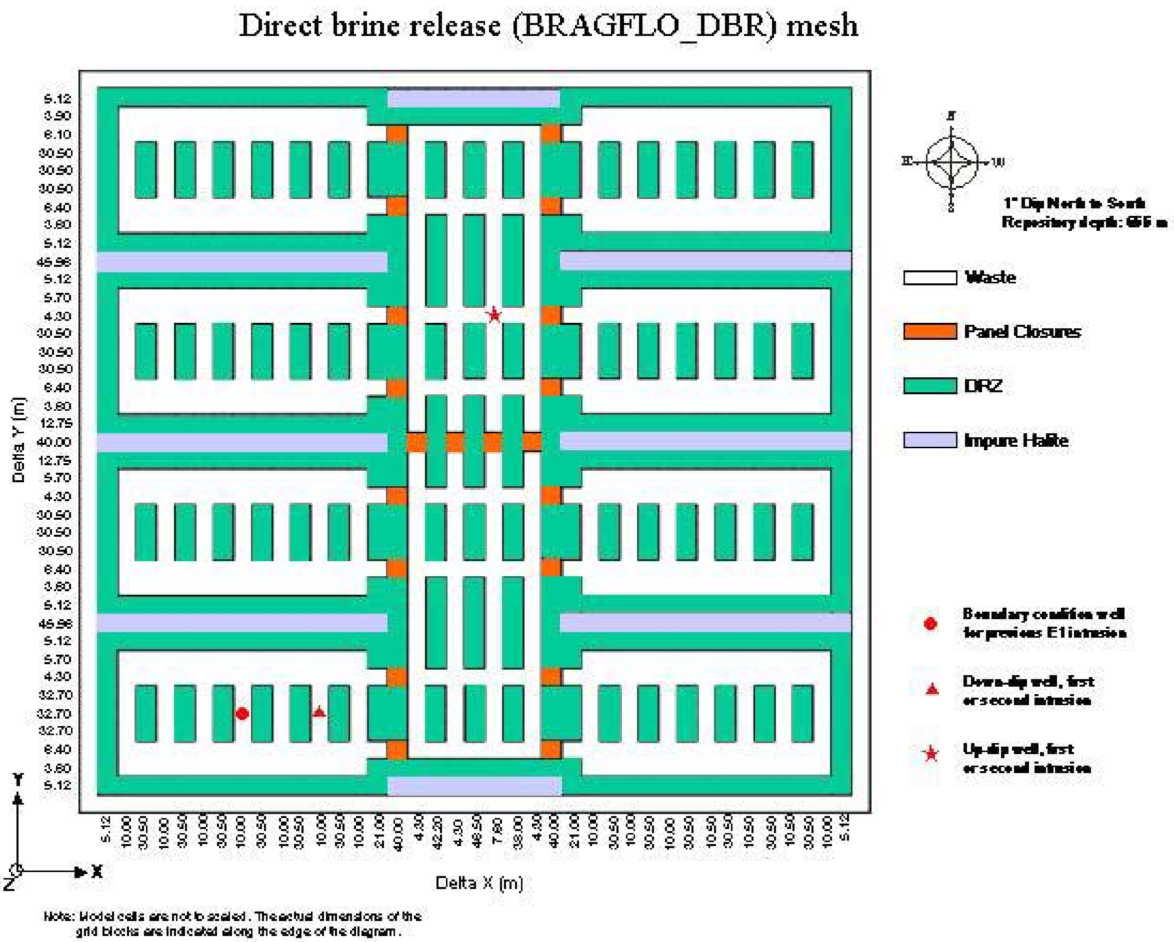
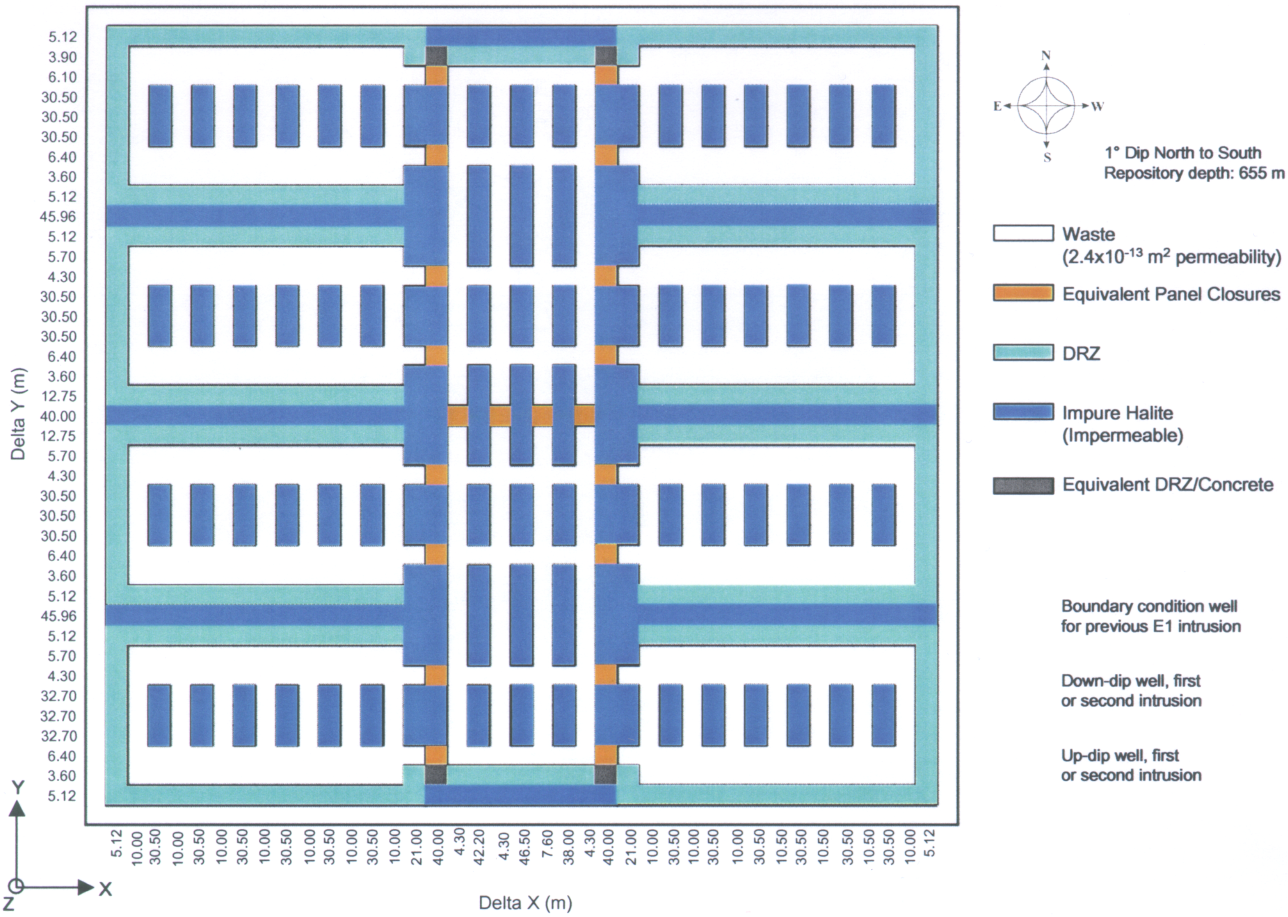


Figure 1: Logical grid used for the CCA and PAVT Direct Brine Release Analyses

Direct brine release (BRAGFLO_DBR) mesh



Note: Model cells are not to scaled. The actual dimensions of the grid blocks are indicated along the edge of the diagram.

Figure 2: Grid to be used for the TBM Direct Brine Release Analysis

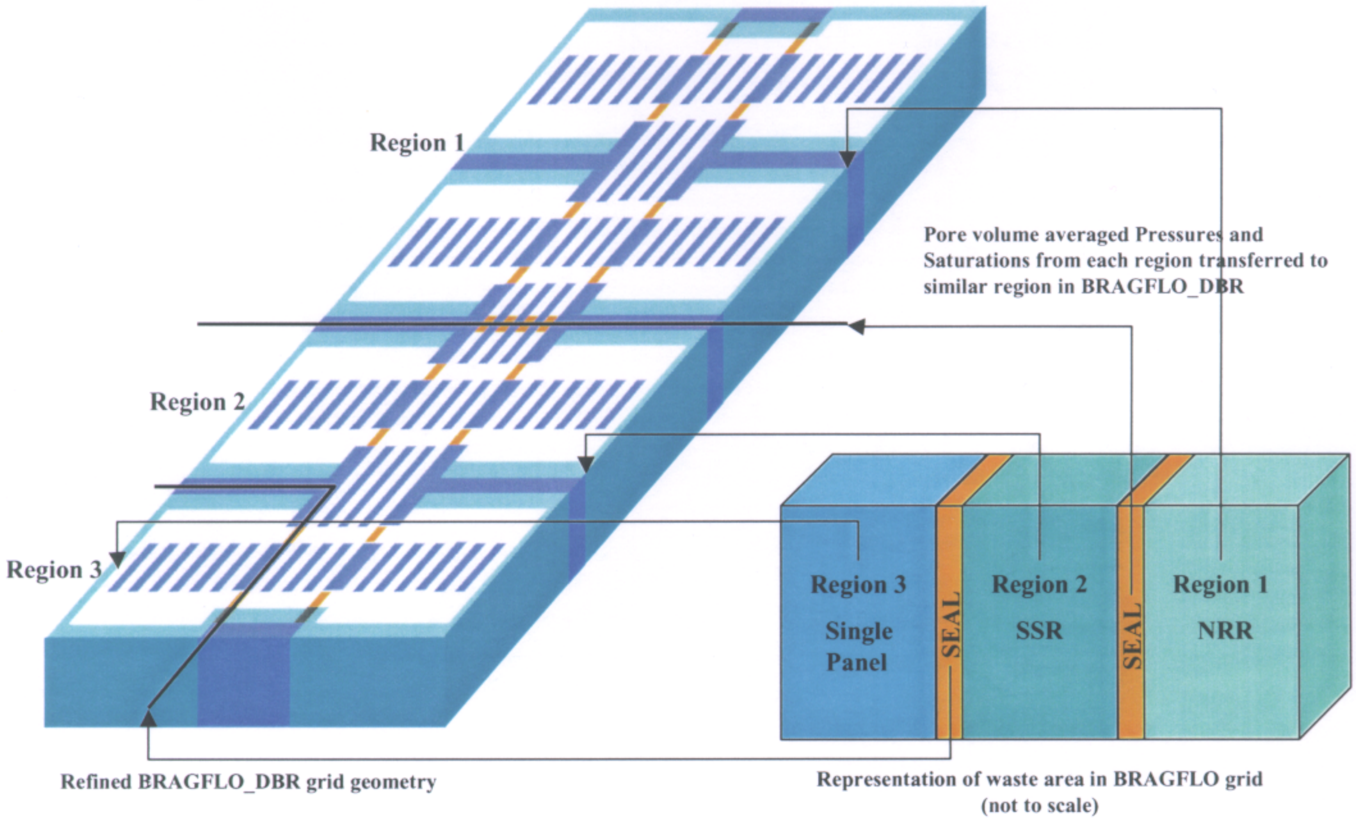


Figure 3: A schematic diagram representing transfer of initial condition variables between the vertical BRAGFLO 10,000-year grid and the horizontal DBR grid for the TBM calculations.

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